

CLAIMS

What is claimed is:

1 1. An apparatus to limit power to a load, comprising:
2 a power source to drive the load using an input signal;
3 a voltage monitor coupled to the power source to detect a voltage supplied by the power
4 source and to provide a voltage signal representative of said voltage;
5 a current monitor coupled to the power source to detect a current supplied by the power
6 source and to provide a current signal representative of said current;
7 the control circuit to receive said voltage signal and said current signal, said control
8 circuit to provide a value based on said voltage signal and said current signal according to one or
9 more control parameters; and,
10 a signal attenuator coupled to the power source and the control circuit, the signal
11 attenuator to limit said input signal based on said value.

1 2. The apparatus of claim 1 further comprising an amplifier coupled to the power
2 source and the load.

1 3. The apparatus of claim 2 wherein the amplifier includes the voltage monitor and
2 the current monitor.

1 4. The apparatus of claim 1 wherein the voltage signal is sampled by a first analog-
2 to-digital converter to generate a digital voltage signal.

1 5. The apparatus of claim 4 wherein the current signal is sampled by a second
2 analog-to-digital converter to generate a digital current signal.

1 6. The apparatus of claim 5 wherein the control circuit further comprises a multiplier
2 to receive the digital voltage signal and the digital current signal, and to calculate an
3 instantaneous power.

1 7. The apparatus of claim 1 wherein the control circuit implements a linear gain
2 control.

1 8. The apparatus of claim 1 wherein the control circuit implements a nonlinear gain
2 control.

1 9. The apparatus of claim 1 wherein the control circuit implements a recursive gain
2 control.

1 10. The apparatus of claim 1 wherein the control circuit implements a non-recursive
2 gain control.

1 15. The apparatus of claim 14 wherein the release coefficient is calculated by the
2 control circuit according to,

$$T_R = e^{\frac{-n}{t_R f_s}},$$

4 where n is a filter order, t_R is the release time, and f_s is a sampling frequency.

1 16. The apparatus of claim 1 wherein the one or more control parameters are selected
2 from a library of control parameters that is accessible using a graphical user interface.

1 17. The apparatus of claim 16 wherein the load is a loudspeaker and the library of
2 control parameters comprises optimized control parameters for a plurality of particular
3 loudspeakers.

1 18. The apparatus of claim 17 wherein the one or more control parameters are
2 selected by a user from the library of control parameters by selecting from a list of available
3 loudspeakers using the graphical user interface.

1 19. The apparatus of claim 1 wherein the one or more control parameters are
2 manually provided to the control circuit by a user.

1 20. The apparatus of claim 1 wherein said one or more control parameters comprises
2 a thermal threshold value.

1 21. The apparatus of claim 20, wherein the thermal threshold value is calculated
2 according to,

3
$$\frac{R_T}{R_0} = 1 + \alpha(T_T - T_0) + \beta(T_T - T_0)^2,$$

4 where α and β are thermal coefficients of resistance, T_0 is a resistance of said load at
5 ambient temperature and T_T is a threshold temperature of the load.

1 22. The apparatus of claim 21, wherein said value is a gain value, and wherein the
2 control circuit calculates said gain value using the thermal threshold value expressed as follows:

3
$$gain = \frac{R_0 A_I I}{R_T A_V I_0},$$

4 where A_I is a corrective factor for the current signal, A_V is a corrective factor for the
5 voltage signal, I_0 is representative of a modeled current and I is representative of a measured
6 current.

1 23. An apparatus to limit power to a load, comprising:
2 a power source to drive the load;
3 a monitor coupled to the power source to detect a power level supplied by the power
4 source and to provide a power signal representative of said power level;

5 the control circuit to receive said power signal and to provide a value based on said
6 power signal according to one or more control parameters; and,
7 a signal attenuator coupled to the power source and the control circuit, the signal
8 attenuator to limit said power level based on said value.

1 24. The apparatus of claim 23 further comprising an amplifier coupled to the power
2 source and the load.

1 25. The apparatus of claim 24 wherein the amplifier includes the monitor.

1 26. The apparatus of claim 23 wherein the power signal is sampled by an analog-to-
2 digital converter to generate a digital power signal.

1 27. The apparatus of claim 26 wherein the control circuit further comprises a
2 multiplier to receive the digital power signal, and to calculate an instantaneous power.

1 28. The apparatus of claim 23 wherein the control circuit implements a linear gain
2 control.

1 29. The apparatus of claim 23 wherein the control circuit implements a nonlinear gain
2 control.

1 30. The apparatus of claim 23 wherein the control circuit implements a recursive gain
2 control.

1 31. The apparatus of claim 23 wherein the control circuit implements a non-recursive
2 gain control.

1 32. The apparatus of claim 23 wherein the one or more control parameters includes a
2 power averaging time and a power threshold.

1 33. The apparatus of claim 32 wherein the one or more control parameters further
2 includes an attack time and a release time.

1 34. The apparatus of claim 32 wherein an averaging coefficient (T_A) is calculated by
2 the control circuit using the power averaging time according to $T_A = e^{\frac{-n}{t_a f_s}}$, where n is a filter
3 order, t_a is the power averaging time in seconds, and f_s is a sampling frequency.

1 35. The apparatus of claim 33 wherein said value is a gain value, and wherein the
2 control circuit calculates the gain value using the power threshold according to,

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$$gain = \sqrt{\frac{P_T A_I A_V}{L}},$$

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where L is an averaged power level, P_T is the power threshold, A_I is a corrective factor for the current signal, A_V is a corrective factor for the voltage signal and T_R is a release coefficient.

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36. The apparatus of claim 35 wherein the recovery coefficient is calculated by the control circuit expressed as follows:

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$$T_R = e^{\frac{-n}{t_R f_s}},$$

4

where n is a filter order, t_R is the release time and f_s is a sampling frequency.

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37. The apparatus of claim 23 wherein the one or more control parameters are selected from a library of control parameters that is accessible using a graphical user interface.

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38. The apparatus of claim 37 wherein the load is a loudspeaker and the library of control parameters contains optimized control parameters for a plurality of particular loudspeakers.

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39. The apparatus of claim 38 wherein the one or more control parameters are selected by a user from the library of control parameters by selecting from a list of available loudspeakers using the graphical user interface.

1 40. The apparatus of claim 23 wherein the one or more control parameters are
2 manually provided to the control circuit by a user.

1 41. The apparatus of claim 23 wherein said one or more control parameters comprises
2 a thermal threshold value.

1 42. The apparatus of claim 41, wherein the thermal threshold value is calculated
2 according to,

3
$$\frac{R_T}{R_0} = 1 + \alpha(T_T - T_0) + \beta(T_T - T_0)^2,$$

4 where α and β are thermal coefficients of resistance, T_0 is a resistance of said load at
5 ambient temperature and T_T is a threshold temperature of the load.

1 43. The apparatus of claim 42, wherein said value is a gain value, and wherein the
2 control circuit calculates said gain value using the thermal threshold value expressed as follows:

3
$$gain = \frac{R_0 A_I I}{R_T A_V I_0},$$

4 where A_I is a corrective factor for the current signal, A_V is a corrective factor for the
5 voltage signal, I_0 is representative of a modeled current and I is representative of a measured
6 current.

1 44. A method for limiting power to a load comprising:
2 driving the load with an input signal;

3 providing a voltage signal that is representative of a voltage of the input signal;
4 providing a current signal that is representative of a current of the input signal;
5 calculating a value based on said voltage signal and said current signal according to one
6 or more control parameters; and,
7 limiting the input signal based on the value.

1 45. The method of claim 44 further comprising amplifying the input signal before
2 said driving the load with the input signal.

1 46. The method of claim 44 further comprising generating a digital voltage signal by
2 sampling the voltage signal with a first analog-to-digital converter.

1 47. The method of claim 44 further comprising generating a digital current signal by
2 sampling the current signal with a second analog-to-digital converter.

1 48. The method of claim 47 further comprising calculating an instantaneous power by
2 combining the digital voltage signal and the digital current signal.

1 49. The method of claim 44 further comprising implementing linear gain control
2 using a control circuit that is used for said calculating the gain value.

1 50. The method of claim 44 further comprising implementing nonlinear gain control
2 using a control circuit that is used for said calculating the gain value.

1 51. The method of claim 44 further comprising implementing recursive gain control
2 using a control circuit that is used for said calculating the gain value.

1 52. The method of claim 44 further comprising implementing non-recursive gain
2 control using a control circuit that is used for said calculating the gain value.

1 53. The method of claim 44 wherein the one or more control parameters includes a
2 power averaging time and a power threshold.

1 54. The method of claim 53 wherein the one or more control parameters further
2 includes an attack time and a release time.

1 55. The method of claim 53 further comprising calculating an averaging coefficient
2 (T_A) using the power averaging time according to $T_A = e^{\frac{-n}{t_a f_s}}$, where n is a filter order, t_a is the
3 power averaging time in seconds, and f_s is a sampling frequency.

1 56. The method of claim 54 wherein said value is a gain value, the method further
2 comprising calculating the gain value using the power threshold according to,

$$3 \quad \text{gain} = \sqrt{\frac{P_T A_I A_V}{L}},$$

4 where L is an averaged power level, P_T is the power threshold, A_I is a corrective factor
5 for the current signal, A_V is a corrective factor for the voltage signal and T_R is a release
6 coefficient.

1 57. The method of claim 56 further comprising calculating the release coefficient
2 according to,

$$3 \quad T_R = e^{\frac{-n}{t_R f_s}},$$

4 where n is a filter order, t_R is the release time and f_s is a sampling frequency.

1 58. The method of claim 44 further comprising selecting the one or more control
2 parameters from a library of control parameters that is accessible using a graphical user interface.

1 59. The method of claim 58 wherein the load is a loudspeaker and the library of
2 control parameters comprises optimized control parameters for a plurality of particular
3 loudspeakers.

5 where A_I is a corrective factor for the current signal, A_V is a corrective factor for the
6 voltage signal, I_0 is representative of a modeled current and I is representative of a measured
7 current.

1 65. A method for limiting power to a load comprising:
2 driving the load with an input signal from a power source;
3 providing a power signal that is representative of a power level of the input signal;
4 calculating a value based on said power signal according to one or more control
5 parameters; and,
6 limiting the input signal based on the value.

1 66. The method of claim 65 further comprising generating a digital power signal by
2 sampling the power signal with a analog-to-digital converter.

1 67. The method of claim 65 further comprising calculating an instantaneous power
2 based on the digital power signal.

1 68. The method of claim 65 wherein the one or more control parameters includes a
2 power averaging time, a power threshold, an attack time and a release time.

1 69. The method of claim 68 further comprising calculating an averaging coefficient

2 (T_A) using the power averaging time according to $T_A = e^{\frac{-n}{t_a f_s}}$, where n is a filter order, t_a is the
3 power averaging time in seconds, and f_s is a sampling frequency.

1 70. The method of claim 68 wherein the value is a gain value, and the method further
2 comprises calculating the gain value using the power threshold according to,

3
$$gain = \sqrt{\frac{P_T A_I A_V}{L}},$$

4 where L is an averaged power level, P_T is the power threshold, A_I is a corrective factor
5 for the current signal, A_V is a corrective factor for the voltage signal and T_R is a release
6 coefficient.

1 71. The method of claim 70 further comprising calculating the release coefficient
2 according to,

3
$$T_R = e^{\frac{-n}{t_R f_s}},$$

4 where n is a filter order, t_R is the release time and f_s is a sampling frequency.

1 72. The method of claim 65 further comprising selecting the one or more control
2 parameters from a library of control parameters that is accessible using a graphical user interface,
3 and wherein said load is a loudspeaker and the library of control parameters contains optimized
4 control parameters for a plurality of particular loudspeakers.

1 73. The method of claim 72 wherein said selecting the one or more control
2 parameters comprises selecting the one or more control parameters from the library of control
3 parameters by selecting from a list of available loudspeakers using the graphical user interface.

1 74. The method of claim 65 wherein said one or more control parameters comprises a
2 thermal threshold value.

1 75. The method of claim 74 further comprising calculating the thermal threshold
2 value according to,

3
$$\frac{R_T}{R_0} = 1 + \alpha(T_T - T_0) + \beta(T_T - T_0)^2,$$

4 where α and β are thermal coefficients of resistance, T_0 is a resistance of said load at
5 ambient temperature and T_T is a threshold temperature of the load.

1 76. The method of claim 75, wherein said value is a gain value, and wherein the
2 method further comprises control circuit calculates said gain value using the thermal threshold
3 value expressed as follows:

4
$$gain = \frac{R_0 A_I I}{R_T A_V I_0},$$

5 where A_I is a corrective factor for the current signal, A_V is a corrective factor for the
6 voltage signal, I_0 is representative of a modeled current and I is representative of a measured
7 current.